International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 9 Issue 4, Jul-Aug 2025 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Internet of Things in Law Enforcement

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ABSTRACT

Internet of things (IoT) refers to the network of interconnected physical devices, vehicles, buildings, and other objects embedded with sensors, software, and network connectivity, enabling them to collect and exchange data. The use of IoT technology is rapidly transforming various industries, and law enforcement is no exception. IoT is revolutionizing law enforcement by providing real-time data, enhancing situational awareness, and improving response times. It is providing new tools and capabilities that can enhance surveillance, improve communication, and enable data-driven decision-making. In this paper, we will explore the basics of IoT and its integration into law enforcement.

KEYWORDS: *Internet of things, IoT, industrial Internet of things, IIoT, policing, law enforcement.*

How to cite this paper: Matthew N. O. Sadiku | Paul A. Adekunte | Janet O. Sadiku "Internet of Things in Law Enforcement" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-9 | Issue-4, August 2025, pp.656-666, URL: www.ijtsrd.com/papers/ijtsrd97312.pdf

IJTSRD97312

INTRODUCTION

Under mounting pressure to do more with less budget, law enforcement agencies are increasingly turning to technology, such as the Internet of things (IoT), to improve operational efficiencies, increase transparency and safety, and better collaborate across their police forces. Connectivity bandwidth determines how much and how quickly data can get exchanged to and from the device, and significantly impacts what they are capable of and how law enforcement can benefit from the technology. For example, IoT-enabled body cameras equipped with GPS tracking capabilities can allow agencies to monitor the location of officers, improving officer safety and enabling the more effective deployment of resources during emergencies [1].

Connected devices like cameras, sensors, and wearables generate a massive amount of data that can be used to prevent, investigate, and solve crimes. They add eyes and ears around our homes, inside our cars, and on our bodies. The proliferation of connected devices provides expansive opportunities for the government to assemble detailed portraits of people's lives. These devices collect information from inside the home - a space explicitly safeguarded by the Fourth Amendment and protected by courts against both technological and physical intrusions. The Fourth Amendment protects "persons, houses, papers, and effects" from unreasonable searches and seizures. The information collected by connected devices can reveal not only the location of a person's home or workplace, but also their associations and their participation in constitutionally protected activities such as prayer and protest.

Police has already come calling for this information generated by the so-called "Internet of things," with significant privacy implications for Americans. The term "Internet of things" refers to the network of physical objects embedded with sensors, software and other technologies that connect and exchange data with other devices and systems over the Internet. In the context of law enforcement, IoT devices can include a wide range of technologies, such as surveillance cameras, environmental sensors, body-worn cameras, connected vehicles and, in some cases, some specialized equipment we use during certain operations, such as drones and robots [2]. The deep

well of data these devices create allows law enforcement to analyze a person's proximity to a crime, assess relationships between victims and suspects, and even review recordings of incriminating statements. If police want to obtain real-time communications from connected devices, they will typically need to obtain a special wiretap warrant. It is increasingly common for law enforcement officers to collect data from connected devices as part of an investigation, and not always under judicial supervision. Short of situations where the law clearly requires the government to obtain a warrant or follow another legal process, corporate decisions to disclose data to law enforcement will in most circumstances be governed by their privacy policies. By relying on private connected devices, police are able to achieve increasingly comprehensive views into where people go and what they say. Not only is this incompatible with the right to privacy, it can have a chilling effect on other constitutional rights like the right to free expression, as omnipresent government eyes and ears can make people less comfortable with expressing controversial thoughts and beliefs - even within the privacy of a home [3].

OVERVIEW OF INTERNET OF THINGS

The concept of the Internet of things (IoT) has been around since the late 1990s, but it gained momentum in the 2000s with the rise of Internet-connected devices. The Internet began with some military computers in the Pentagon called Arpanet in 1969. It expanded throughout the 1980s as a set of four parallel military networks, each at a different security level. The core technology which gives the Internet its particular characteristics is called Transmission Control Protocol/Internet Protocol (TCP/IP), which is essentially a set of rules for communication [4].

Internet of things (IoT) is a worldwide network that connects devices to the Internet and to each other using wireless technology. These devices contain hardware such as sensors and electronics which give them the ability to interact with other objects and to be monitored and controlled from afar. The idea is that the physical devices with sensors or the ability to capture data, shares that data with websites. The information is then used or analyzed in real time or at a later time, to create efficiencies. IoT is expanding rapidly and it has been estimated that 50 billion devices will be connected to the Internet by 2020. These include smart phones, tablets, desktop computers, autonomous vehicles, refrigerators, toasters, thermostats, cameras, alarm systems, home appliances, insulin pumps, industrial machines, intelligent wheelchairs, wireless sensors, mobile robots, etc. Figure 1 illustrates the Internet of things [5].

There are four main technologies that enable IoT [6]: (1) Radio-frequency identification (RFID) and near-field communication, (2) Optical tags and quick response codes: This is used for low cost tagging, (3) Bluetooth low energy (BLE), (4) Wireless sensor network: They are usually connected as wireless sensor networks to monitor physical properties in specific environments. Communications technologies in Internet of things are portrayed in Figure 2 [7].

IoT technology enables people and objects to interact with each other. It is employed in many areas such as smart transportation, smart cities, smart energy, emergency services, healthcare, data security, industrial control, logistics, retails, structural health, traffic congestion, manufacturing, and waste management. The Internet of things is extensively developed world-wide with a focus on civilian applications such as electric power distribution, intelligent transportation, healthcare, industrial control, precision agriculture, environmental monitoring, etc.

INDUSTRIAL INTERNET OF THINGS

The growth of the internet of things (IoT) is drastically making impact on home and industry. While the IoT affects among others transportation, healthcare, or smart homes, the Industrial Internet of Things (IIoT) refers in particular to industrial environments. IIoT is a new industrial ecosystem that combines intelligent and autonomous machines, advanced predictive analytics, and machine-human collaboration to improve productivity, efficiency and reliability. It is bringing about a world where smart, connected embedded systems and products operate as part of larger systems [8].

The industrial Internet of things (IIoT) refers to the application of the Internet of things (IoT) across several industries such as manufacturing, logistics, oil and gas, transportation, energy/utilities, chemical, aviation and other industrial sectors. A typical industrial Internet of things is shown in Figure 3 [9].

IIoT is often used in the context of Industry 4.0, the Industrial Internet and related initiatives across the globe. Industry 4.0 describes a new industrial revolution with a focus on automation, innovation, data, cyber-physical systems, processes, and people [10]. With Industry 4.0, the fourth industrial revolution is set on merging automation and information domains into the industrial Internet of things, services, and people. The communication infrastructure of Industry 4.0 allows devices to be accessible in barrier-free manner in the industrial Internet of things, without sacrificing the integrity of safety and security [11]. Figure 4 shows a typical representation of IoT [12].

IOT IN LAW ENFORCEMENT

The world we live in today is becoming increasingly interconnected, with technology playing a vital role in our daily lives. Law enforcement agencies face numerous challenges in today's complex and interconnected world. Traditional policing methods are often time-consuming, reliant on manual processes, and can struggle to keep up with the ever-evolving nature of crime. This is where the integration of IoT technology comes into play. Internet of things is a network of interconnected devices, objects or systems that are embedded with software, sensors and network connectivity which allows them to collect, exchange and act upon those data, often without any human intervention. IoT devices can include surveillance cameras, environmental sensors, body-worn cameras, connected vehicles and specialized equipment such as drones and robots. By leveraging IoT devices and the data they generate, law enforcement agencies can gain valuable insights and make data-driven decisions. Figure 5 shows IoT in law enforcement [13].

In the age of rapid technological advancement, the integration of the Internet of things (IoT) into public safety initiatives has become increasingly vital. Although IoT technology is still in its early stages, it has the potential to revolutionize law enforcement. Various law enforcement agencies worldwide have already integrated IoT technology into their operations to achieve significant improvements. For example, in Singapore, the police force implemented a smart lamppost project that combines IoT sensors, video analytics, and data analytics to enhance surveillance and crowd management. In the United States, the Los Angeles Police Department deployed IoT-enabled license plate readers, resulting in increased stolen vehicle recovery rates and improved response times to emergency calls [14]. Figure 6 shows how IoT devices are being used by a police officer [13].

APPLICATIONS OF IOT IN LAW ENFORCEMENT

The integration of Internet of things (IoT) devices into policing is revolutionizing how police departments operate, providing them with innovative tools to enhance efficiency, safety, and effectiveness. IoT devices have become increasingly prevalent in policing, providing law enforcement agencies with real-time data and enhancing their operational capabilities. The following are a few common applications of IoT in law enforcement [15]:

- *Smart City:* Imagine a city equipped with smart streetlights that automatically adjust their brightness based on surrounding conditions, surveillance cameras that can detect suspicious activities and notify law enforcement, or police vehicles fitted with sensors that provide real-time data on traffic patterns and crime hotspots. These are just a few examples of how IoT can enhance the capabilities of law enforcement agencies. Smart cities use IoT technology to enhance urban living, improve services, and promote sustainability. With loT data, city planners can make better informed decisions about infrastructure development, road expansion, and zoning. IoT sensors in buildings can detect fires, gas leaks, or intrusions, and then automatically notify emergency services. One of the key innovations in traffic management is the implementation of smart traffic signals and adaptive traffic control systems that use IoT sensors to monitor traffic flow in real-time. Smart streetlights and utilities can also help reduce operational costs for city governments and citizens. Figure 7 shows a typical smart city [14]. Technology has given police departments the opportunity to use the same advanced technology that is helping to create smart cities.
- *Public Safety*: Internet of things (IoT) applications are transforming public safety and security efforts, such as responding to emergencies, traffic accidents, and natural disasters. These technologies are reshaping many public safety solutions—from identifying suspects using facial recognition, and improving traffic management, to expediting emergency response efforts and being better prepared for natural and other disasters. The IoT market is expanding exponentially because of the public safety sector's adoption of it. Public safety organizations are becoming better at safeguarding communities and saving lives with the help of these smart city applications. Figure 8 depicts how IoT is transforming policing [2].
- *Wild Law Enforcement*: With growing sophistication of organized wildlife crimes, wildlife law enforcement agencies need to be armed with cutting-edge technologies like the Internet of things (IoT) to stay ahead of the criminals. IoT can be leveraged to strengthen the monitoring of wildlife, detection of threats, and response by enforcement officials. Wildlife law enforcement agencies can place IoT enabled cameras equipped with artificial intelligence, facial recognition system, motion sensors, thermal imaging etc. on strategic locations inside and outside the wildlife protected areas. Figure 9

shows a representation of wild law enforcement [16].

- *Smart Vehicles:* Smart vehicles for police officers are equipped with various functionality. These come with cameras and voice recorders to record details of any event. These cars can interact with fire alarm services, ambulances, and trucks. The real-time data exchange enables vehicles to share information about speed, direction, and other critical sensory data, helping to prevent accidents and enhance road safety. Police vehicles equipped with cameras and sensors can automatically communicate with other emergency vehicles, providing real-time updates on incidents.
- *Traffic Management:* IoT technology completely changes traffic management by improving traffic flow, reducing congestion, and enhancing road safety. The IoT-based vehicle-to-infrastructure communication allows for smooth connection of vehicles with traffic controlling systems, making possible the implementation of such features as automatic emergency braking and adaptive cruise control that contribute to the prevention of accidents and thus road safety improvement. With IoT, traffic indicators rework into clever indicators which can help people and criminal authorities. Figure 10 shows smart traffic [13].
- *Body Cameras:* Body cameras capture video and audio evidence, which can be used in investigations and prosecutions. Smart CCTV cameras are another core surveillance tool that has been a mainstay for law enforcement for years and is getting a boost with sophisticated connectivity. With high-speed, low-latency connectivity, no matter what network or location, these cameras can transmit high-quality, real-time video feeds of unfolding events and potential security threats, even in the most challenging environments and inclement weather. Encryption is particularly vital in maintaining the integrity of data collected by body-worn cameras, preserving its accuracy and authenticity.
- *Accident Detection:* IoT technology is being harnessed to detect accidents and incidents on the road using various sensors. Once an accident is detected, these systems can automatically alert emergency services, providing critical information about the location and severity of the incident. This leads to faster response times, potentially saving lives in critical situations.

BENEFITS

The implementation of IoT into the public safety efforts comes with a number of advantages such as real time monitoring and predictive analysis, rapid response, and improved traffic control. By connecting various systems and agencies, a collaborative environment is created, helping information flow seamlessly and reducing police response times. This interconnectedness and real-time data sharing enhance the effectiveness and speed of public safety responses and emergency management. By using IoT devices, law enforcement agencies can improve crime prevention, traffic enforcement, evidence collection, and public safety, making our communities safer and more secure. Other benefits include the following [15]:

- *Emergency Response*: For emergency responders, safety and situational awareness are crucial. Efficient emergency response management is essential for enhancing public safety. IoT data applications are revolutionizing how emergencies are managed, providing a more streamlined and effective response based on a more precise understanding of the resources needed. IoT technology facilitates rapid dissemination of emergency alerts to the public. These systems deliver critical information during natural disasters, incidents, or other emergencies, including weather warnings, evacuation notices, and safety instructions.
- *Disaster Preparedness:* Natural disasters are unpredictable and can have catastrophic consequences. IoT technology is playing a fundamental role in early detection, rapid response, and different strategies for disaster preparedness. IoT sensors are being deployed in areas prone to natural disasters, including earthquakes, hurricanes, and wildfires. These sensors can detect early warning signs.
- *Remote Monitoring:* Critical infrastructure—like power plants, water treatment facilities, and communication networks—play a vital role in disaster management and recovery. IoT technology offers remote monitoring of infrastructure using smart public safety technologies, even in disasters. In the event of a natural disaster or emergency, sensors and public safety IoT devices can provide real-time updates on the condition and functionality of critical infrastructure. If an issue arises, immediate action can be taken to ensure continuity and recovery efforts.
- *Situational Awareness*: IoT devices provide real-time information about unfolding situations, allowing officers to respond more effectively. IoT-enabled devices can provide real-time situational awareness to law enforcement

officers, allowing them to respond more effectively and efficiently to emergencies. For example, automated license plate readers can identify stolen vehicles, and body cameras can capture video evidence.

- *Smart Surveillance:* Smart surveillance systems have been integrated into law enforcement strategies, offering a more efficient and effective way to monitor public spaces. These systems utilize advanced analytics and facial recognition technologies to identify potential threats or wanted individuals, allowing law enforcement to respond quickly and prevent criminal activities. By attaching GPS trackers to vehicles or assets, agencies can track their location in real-time, aiding in the recovery of stolen property and apprehension of suspects.
- *Crime Prevention:* One of the most significant advantages of IoT technology in law enforcement is its ability to proactively prevent and detect crime. IoT devices can be used to monitor potential threats, identify patterns of criminal activity, and proactively prevent incidents. For example, cameras can be used to track people's movements, and sensors can be used to detect unusual sounds or vibrations. This information can be used to identify potential crime hotspots and deploy law enforcement resources accordingly. By deploying IoT devices in public spaces, such as streetlights or public transportation, law enforcement can monitor and analyze data to identify suspicious activities or patterns, helping to prevent crimes before they occur.
- *Traffic Enforcement:* IoT sensors can be used to monitor traffic flow, identify violations, and improve traffic safety. IoT devices can be used to monitor traffic and identify violators. For example, speed cameras can be used to catch speeders, and red light cameras can be used to catch drivers who run red lights. This information can be used to improve traffic safety and reduce accidents.
- *Evidence Collection:* The main objective of IoT is to gather data constantly and transmit it over a connection of devices. This feature of IoT is very helpful in gathering any evidence from a crime scene. IoT devices like smartphones, smartwatches, and cameras can provide valuable evidence in criminal investigations, including location data, communication records, and video footage. For example, sensors can be used to detect fingerprints and DNA, and cameras can be used to record video and audio of the crime scene. This information can be used to help solve crimes and bring criminals to justice.
- *Increased Efficiency:* IoT devices can help law enforcement agencies be more efficient by automating tasks and providing real-time data. By leveraging data from connected devices, law enforcement can quickly assess situations, deploy resources efficiently, and respond to emergencies faster.

CHALLENGES

The challenges with IoT in law enforcement include privacy concerns, data security risks, and the need for robust cybersecurity measures to protect sensitive data. This technology raises significant privacy concerns and challenges related to data management and security. In addition to privacy concerns for the individuals involved, there are legal implications including its admissibility in court. Other challenges include the following [3,17]:

- *Data Privacy*: Connected devices raise serious privacy concerns, as they can reveal sensitive information about people's homes, movements, and interactions with others. Doorbell cameras, smart thermostats, digital assistants, and other always-on devices open up a whole new world of privacy risks when the government has access to their data. The use of IoT devices raises significant privacy concerns, as they collect vast amounts of personal data. In a world where people are subjected to ongoing surveillance by public and private actors, there is an urgent need to update regulatory frameworks and rethink privacy protections to account for the inescapable role of technology companies in everyday life.
- *Data Security:* Given increasing security concerns about how data is handled collected and transmitted in the communications ecosystem, decision-makers purchasing these devices should pay close attention to the integrity and experience of the company that is building this core piece of technology. Law enforcement agencies need to ensure the security of IoT data to prevent unauthorized access and misuse.
- *Data Integrity:* Maintaining the integrity, reliability, and availability of data is a significant matter. Public safety agencies rely on IoT-generated data for real-time decision-making. Any data loss, corruption, or unavailability can have severe consequences. To address these challenges, redundant systems and failover mechanisms are often implemented to make sure critical data is always accessible. Therefore, robust cybersecurity measures and strict data

protection policies must be in place to safeguard the integrity and confidentiality of sensitive information.

- *Bias:* The proliferation of connected devices particularly threatens the civil rights of communities of color. Tools such as facial recognition, speech recognition, and emotion detection have documented racial biases that limit these technologies' ability to accurately identify and understand communities of color. These biases are driving nationwide conversations about whether such tools should be used by police. Police departments across the country are under scrutiny not just for over-policing but for using surveillance technology to target communities of color.
- *Lack of Transparency:* Despite the proliferation of connected devices and law enforcement's appetite for the data, many companies still do not publish public transparency reports at all. While companies like Amazon and Google publish reports revealing disclosures of user data across their entire suite of products, the reports do not break down the number of law enforcement requests by product or specify the type of data provided. This makes it difficult to understand how often police are requesting data from. Efforts to address police surveillance must seek transparency and oversight regarding law enforcement's ability to leverage connected devices and private surveillance systems.
- *Regulation:* To improve human existence, regulation enforcement in an area that plays a critical function in securing people and making sure that they are under protection. There is an ongoing need for new regulations that meaningfully guard individual rights and freedoms in the digital age. Law enforcement can be hard. IoT acts as a device of regulation enforcement that helps reduce exertions and decisions on people through better information, statistics sharing, and superior automation.
- *Secure Storage Solutions:* Data encryption and secure storage solutions are essential to safeguard information collected by IoT devices. It ensures data is transmitted securely, making it difficult for unauthorized individuals to intercept or decipher. Secure storage solutions protect data at rest, so it remains confidential and inaccessible to malicious actors.
- *Ethical Considerations*: The use of IoT in law enforcement raises ethical questions about surveillance, bias, and the potential for misuse of technology. Public safety agencies and organizations must navigate these ethical and privacy concerns with a commitment to transparency, accountability, and compliance with applicable laws and regulations. Establishing clear guidelines for the use of IoT technology in public safety is essential to address these issues and build public trust.
- *Cybersecurity Risks*: IoT devices are vulnerable to cyber-attacks, posing significant security risks. Breaches in connected systems can compromise sensitive law enforcement data, disrupt critical operations, and even jeopardize public safety. Law enforcement agencies must prioritize cybersecurity measures by implementing strong encryption protocols, ensuring regular security updates, and establishing robust authentication mechanisms to protect IoT devices and the data they collect.
- *Interoperability:* IoT applications in public safety often involve a multitude of devices, systems, and data streams. As these deployments grow in complexity and scale, challenges in scalability and interoperability emerge. A recent survey on public safety communication concerns ranked interoperability as one of the top three concerns among all respondents. It was also the top requested functionality among law enforcement professionals. However, the crucial interoperability that helps agencies protect their communities can be difficult to establish—especially when natural disasters impact public communication infrastructure. Culture change is necessary to create the innovative, adaptive police departments of the future.
- *Changing Workforce*: Recruiting the next generation of law enforcement officers is already a challenge. Demographic and technological shifts have changed what younger officers expect from the profession. Younger officers are digital natives and have a different culture. They are more likely to think about policing as a job versus profession—do it for a few years and then move on to something else versus serving 20 years and retiring. New technology trends are also changing the society that law enforcement must police. While many of the examples for these shifts in policing come from North America, similar changes are underway across the globe.

CONCLUSION

Law enforcement agencies have embraced the use of IoT devices to revolutionize their practices. For example, body-worn cameras have become a staple for police officers, enabling them to capture video

evidence and ensure transparency in their interactions with the public. IoT offers significant potential for improving law enforcement and public safety. However, it is crucial for agencies to address the challenges related to data privacy, security, and ethical considerations to ensure responsible and effective use of connected devices.

Policing has been evolving for centuries and will continue to do so for centuries to come. Law enforcement agencies globally are facing budget constraints pushing them to look for new ways to become more efficient. Emerging technologies, such as IoT, are enabling them to do so. IoT devices, such as connected sensors and smart cameras, are being used to improve law enforcement operations. These devices provide state and local agencies with a force multiplier. They make data collection and processing more efficient, allowing for quicker and more accurate responses in an emergency. The Internet of things also represents the next generation of security threats. More information about Internet of things in law enforcement can be found in the books in [18,19] and the following related journal: *IEEE Internet of Things Journal.*

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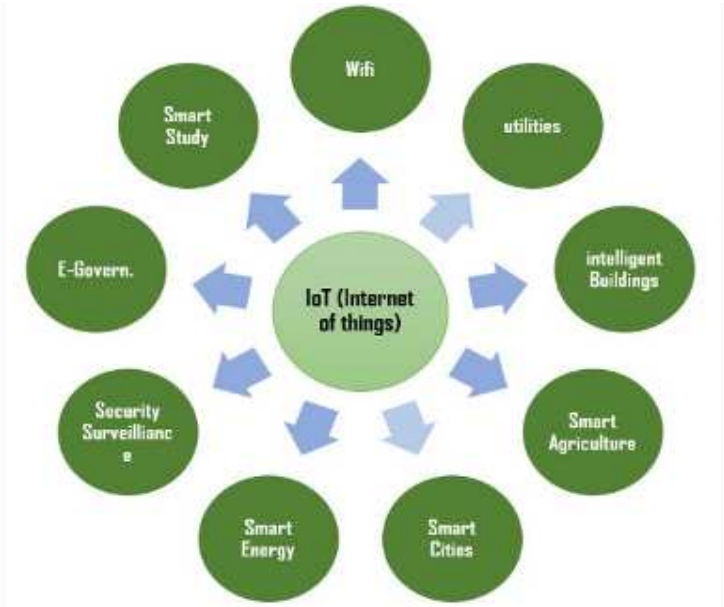

Figure 1 The Internet of things [5].

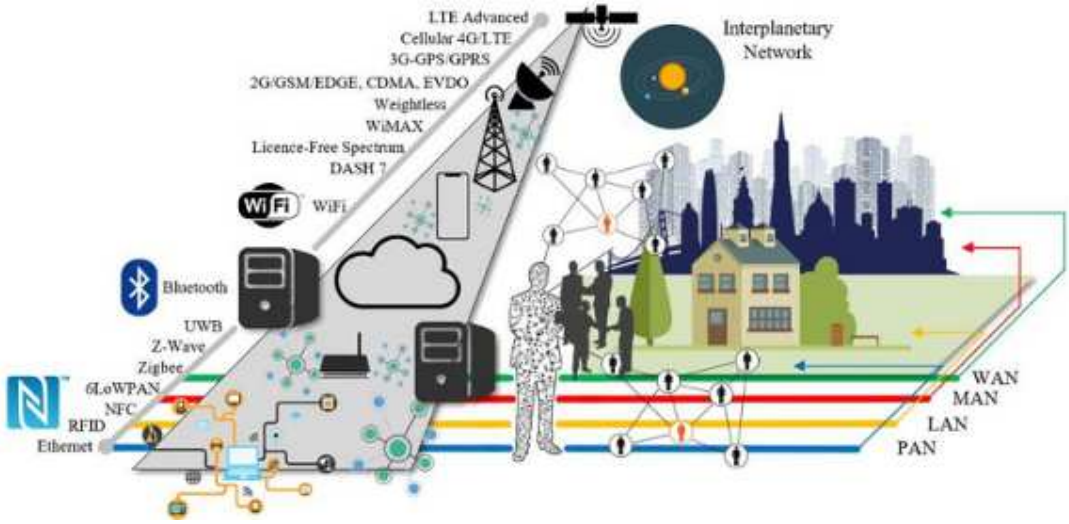

Figure 2 Communications technologies in Internet of things [7].

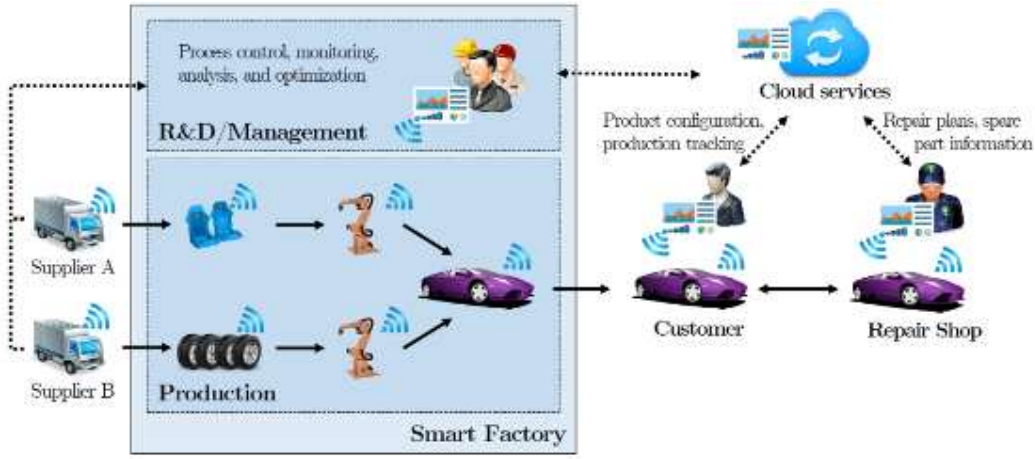

Figure 3 A typical industrial Internet of things [9].

Figure 4 A typical representation of IoT [12].

Figure 5 IoT in law enforcement [13].

Figure 6 How IoT devices are being used by a police officer [13].

Figure 7 A typical smart city [14].

Figure 8 How IoT is transforming policing [2].

Figure 9 A representation of wild law enforcement [16].

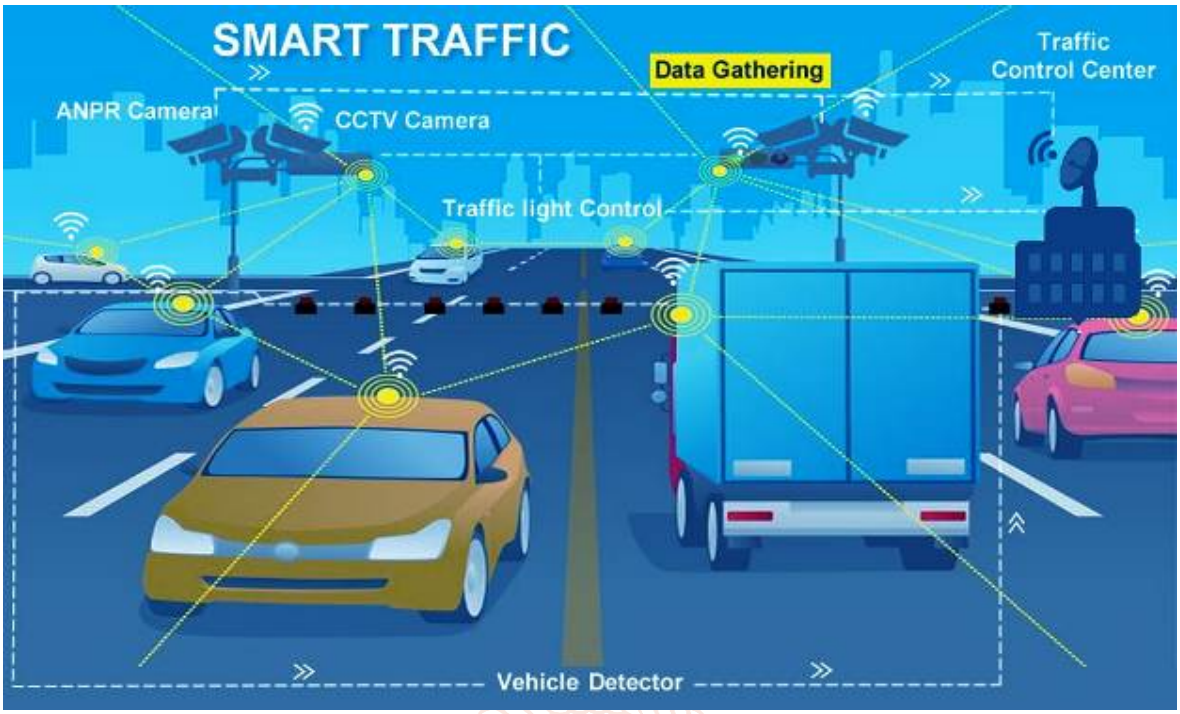

Figure 10 Smart traffic [13].